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BEACH EROSION: CASE STUDIES ON THE EAST AFRICAN COAST

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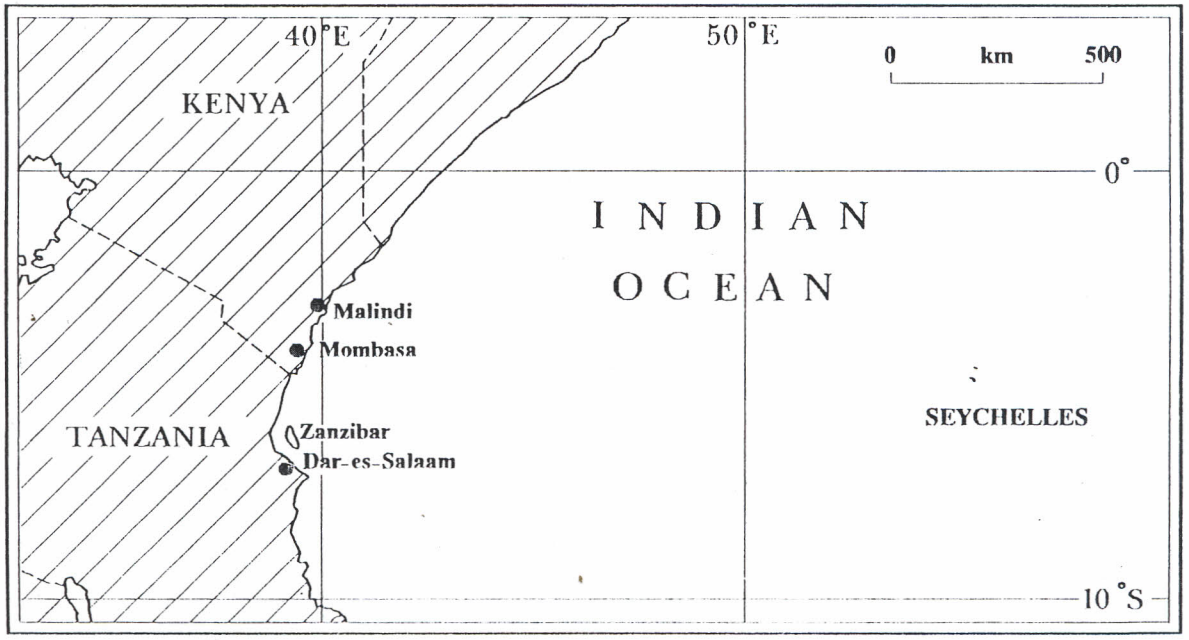
Introduction

Marine erosion of late Holocene beach deposits is a common problem on the equatorial coasts of the western Indian Ocean, damaging or threatening tourism-related investment and communication infrastructure. The problem is acute in Tanzania, both on the mainland in the vicinity of Dar-es-Salaam and on the islands of Zanzibar and Pemba. In Kenya erosion affects resort developments both north and south of Mombasa, while in the Seychelles it affects particularly the islands of Praslin and La Digue.

Physical Setting

The coasts of the region are typically coral reef-fringed. A reef wall forms the seaward fringe to an intertidal to subtidal platform tens to hundreds of metres wide and formed of lithified lagoonal and littoral carbonate sediments. This platform extends inshore to a present-day beach of mobile sand or pebbly sand, commonly dominated by biogenic carbonate. Along many parts of these coasts the mobile beach deposits are banked against older beach sands that form a flat vegetated hinterland some 2m above mean sea level and extending again tens to hundreds of metres inshore. These sands are up to 3m thick and rest on a concealed inshore extension of the lithified platform. They accumulated when the sea level was within a half a metre or so of its present level. The coasts are generally mesotidal, with a range of 2 to 3m. Prevailing winds for the region between November and April blow from the north or north-east, the North-East Monsoon. For the remainder of the year they blow from the south, the South-East Trades becoming the South-West Monsoon as they blow northwards across the equatorial zone. The ocean current regime of this part of the Indian Ocean changes twice during the year, driven by these climatic changes.



Susceptibility to Erosion

It is the older beach sands - those forming the vegetated hinterland - that are particularly prone to erosion leading to coastal recession. Their susceptibility depends on the condition of the present-day beach, the deposits of which provide natural protection against wave energy transmitted across the fringe reef and rock platform during high tide and, particularly, storm events. Where the natural recharge of sediment on the beach exceeds wastage then a stable or accretionary beach is established. Conversely where wastage exceeds recharge, the beach's protective role becomes ineffective and the older beach sands of the hinterland are exposed to wave energy and thus prone to erosion.

The Sites Described

This paper presents outlines of the geomorphology and sedimentary regime at nine sites selected by local scientists and coastal managers. At seven of these sites erosion is causing particular local concern. At one of the remaining sites long-term sediment accretion prevails. The descriptions are based on study visits by the author during April 1992. The paper discusses the natural controls and influences on the sedimentary regime at each site, and considers the possible contributions to coastal instability due to the activities of man.

Tanzanian Mainland Coast North of Dar-es-Salaam

Bahari Beach and Kunduchi Beach are the sites of resort developments respectively 25 and 20km north of Dar-es-Salaam. The coast here faces north-east onto the southern end of the Zanzibar Channel. Shallow waters strewn with patch reefs and sand shoals extend for some 10km from the shore. The hotel buildings at each site were constructed on older beach sands forming a vegetated hinterland with mature coconut palms that extended several tens of metres beyond its present seaward limit. During the period from the late 1970s to the mid-1980s there was major marine erosion of the hinterland immediately adjoining the resorts, and the backshore with its associated storm deposits approached to within a few metres of the principal hotel buildings.

At Bahari the affected coast extends for some 2km from a rock headland, Ras Kiromoni, in the north to a spit in the south. This spit is reported to have accreted substantially during the same period. The form of the spit and its adjoining beach deposits indicates a present net southward longshore drift. A major programme of beach stabilization was carried out during the late 1980s in an attempt to prevent further erosion. Coast-perpendicular groynes were constructed at intervals of 20 to 30m along the affected shore using locally quarried limestone blocks up to 1m or so across. Similar material was used for rip-rap armour as a backshore protection. As an additional measure concrete culvert pipes were embedded parallel to the shoreline in the beach sands although most of these have become displaced or damaged and contribute little if anything to stabilization. At the time of the site visit the beach sands at the hotel were confined to pockets between the groynes, the foreshore to seaward of the groynes being of beach rock.

At Kunduchi major erosion affects the shore for some 0.5km both north and south of the principal hotel buildings. The older beach sands of the vegetated hinterland have been stripped back by several tens of metres since the resort was developed in the early 1970s

to reveal a foreshore of beach rock. As at Bahari there has been some sediment accretion to the south of the erosion zone with the growth of a major, reportedly new, sand spit building north-eastwards immediately south of Kunduchi Creek. In addition two much smaller finger-like sand shoals of similar trend are present on the foreshore off the hotel frontage. Rock groynes a metre or so high have been constructed adjacent to the hotel, but these appear to be largely ineffective under present conditions. The resort remains seriously at risk from further erosion, the backshore now lying within 20m of the main hotel buildings. A soft-engineered protective solution involving recharge of the beach to the north of the resort using sand extracted from the adjacent shoals or spit might be a viable, environmentally appropriate option in this case.

Zanzibar Island, Tanzania

Ras Nungwi at the northern tip of Zanzibar Island, some 55km north of Zanzibar town, provides an example where a change of sediment transport regime over the last few years has lead to a dramatic change in coastal geomorphology. The coast of this northern peninsula mostly comprises low cliffs of limestone flanked by a coral reef-fringed intertidal platform up to 2km wide. On the 1km-long north-facing shore west of the lighthouse at Ras Nungwi, the cliff line gives way to a hinterland composed of older beach sands 2 to 3m thick, and lying some 3m above mean sea level. The fishing village of Nungwi is situated on this shelf. Until the mid-1970s the older sands extended as a coconut palm plantation for more than 100m north of its present limit. Since then major erosion of these sands has occurred, the shoreline retreating to expose an increasing expanse of intertidal platform. Continuing erosion now threatens the northern part of the village itself.

The present-day mobile beach sands of this north-facing shore form an apron some 50m wide banked against an erosional backshore scarp of older beach sands up to 1m high. The remains of a failed sea wall, reported to have been constructed within the last five years in an attempt to protect the village, are embedded within this apron, along with displaced palm stumps. The direction of net sand transport is westwards along this shore. The broad intertidal platform of the adjoining north-east-facing shore, south-east of Ras Nungwi, is free from substantial sand deposits but for an impoverished beach. The corresponding platform of the west-facing shore, to the west of the village, is only some 200m wide but carries conspicuous sand bodies. The sand extends as banks from an accreting beach apron to the edge of the reef fringe, where there appears to be a loss of sand from the platform into an adjoining deep water channel.

The onset of the erosional regime at Ras Nungwi is believed to be due to a cessation or reversal of a north-westward longshore drift along the north-east-facing shore and platform of the peninsula; this reversal effectively starving the adjoining north-facing beach apron. This apron provided the only protection to the vegetated hinterland against wave attack and consequent shoreline recession.

Mombasa Coast, Kenya

The Kenya coast for some 50 or more kilometres north of Mombasa faces ESE and presents a rather uniform geomorphology. A coral reef-fringed intertidal to subtidal

platform of lithified sediments with thin patches of mobile sand extends largely uninterrupted up to 1km wide and is covered to landward by a sandy beach strand. Typically the beach sands are banked against coastal hinterland deposits of older beach sand up to three metres thick, resting on concealed platform rock or, at their inland limit, banked in turn against older rocks forming the rising ground. In a few places, notably at Mombasa, Mtwapa and Kilifi, the platform and its fringing reef are cut by deep channels that extend inland as drowned valleys with fringing mangrove.

Kikambala and Kanamai are adjoining resorts on the coast between Mtwapa and Kilifi creeks. At both locations a sand strand separates an intertidal platform from a coastal hinterland of older beach sand. At Kikambala a resort complex has been constructed on older beach sands that extend for some 3km along the coast between rock headlands. These older sands are subject to erosion during high-water storm events, with sand and scattered pumice pebbles accumulating as a levee deposit along the crest of the erosional scarp. The hotel complex is presently bounded at the backshore by a vertical concrete wall. Similar erosion of the older sands was noted on the shore a few kilometres further south at Kanamai, where numerous coastal properties are affected by shoreline recession. Attempts to arrest the recession have been made by the use of concrete walls, but these show signs of failure as a result of undercutting. Elsewhere armouring with blocks of quarried rock has been tried, but this protection has also failed, apparently because the blocks used were not large enough to withstand storm wave attack. It is unclear how long these shores have been recessive. It is however clear that the sedimentary regime at these sites differs significantly from that in which the older beach sands accreted so extensively along this coast. These modern beaches are relatively starved of sand and are ineffective as protectors of the older beach sand hinterland.

Malindi and Mambrui, Kenya

At and to the north of the resort town of Malindi, 105km NNE of Mombasa, the contemporary beach sands and silts are dominated not by calcium carbonate as they are to the south but by terrigenous sediments - quartz, mica and dark minerals derived via the Sabaki River from the hinterland as far distant as Nairobi and the eastern slopes of Kilimanjaro. The river flows out to the sea 6km north of the resort. The promontory at the southern end of the Malindi bay is reported as forming a divide between the two contrasting sediment cells.

Whereas on the Mombasa coast to the south erosion is a major cause of management concern, the problems at Malindi are due to sediment accretion. The accretion is said to have become particularly significant over the last 20 years or so. Beach hotels and dwellings constructed up until the early 1970s in the coastal strip directly adjoining what was then the backshore in the northern part of the resort are now distant from the shore by a hundred metres or more, the intervening sands accreted since then being vegetated with scrub and immature coconut palms. Further south an inclined concrete sea wall constructed as a protection to the coastal road is now partially buried by sand with a thin cover of vegetation.

The maintenance of the dominant accretionary regime at Malindi during the last 20 years may have been supported by an increased flux of sediment from the Sabaki River, perhaps

reflecting changing agricultural practice in the hinterland. However, even with an increased sediment supply, it seems that the longshore sediment transport regime has been modified, resulting in a dramatic increase in the supply of sand and silt southwards to the Malindi bay.

At Mambrui, 6km north-east of the mouth of the Sabaki River, beach sand derived from the Sabaki is plentiful, forming an apron some 100m wide on a lithified intertidal platform. To the north and south of the village the beach is flanked by sand dunes some of which are more than 20m high. In places the dune sands extend as lobes over the backshore. The dunes have advanced in recent years into the southern outskirts of the village, so that some buildings have become engulfed by sand and abandoned.

Praslin and La Digue, Seychelles

Praslin and La Digue are two of the granitic islands of the Seychelles island group. They lie on the north-eastern side of the Seychelles Bank, a platform formed on an isolated fragment of continental crust. Apart from the granitic islands the platform has a subdued relief and its covering seas are generally less than 60m deep. Both islands are partially reef-fringed with intertidal lithified, mainly carbonate, platforms. Typically these platforms are flanked to landward by a flat hinterland of older beach sands with an intervening strand.

On Praslin erosion on the west-facing shore of Anse Kerlan, near to the island's airstrip, is a cause of concern. Wastage of contemporary beach sands has led to erosion of an older beach hinterland, some 700m wide and bounded to the north by a granite headland. The erosion has encroached upon a coastal road, necessitating its diversion. In an attempt to stabilize the beach sands a number of groynes have been constructed using granite blocks, while part of the backshore has been armoured with rip-rap of similar material.

At La Passe on La Digue a flat, vegetated hinterland of older beach sands, up to 1km wide and bounded to the north by the granite headland of Cap Barbu, is being eroded. The erosion is threatening the coastal road and causing an immediate danger to a number of buildings including a fish collection centre. Parts of the backshore are strewn with fallen palm trunks, undermined by the erosion. The shore here faces west-north-west. The present-day beach deposits, which comprise carbonate and quartz sand mixed with coarser fragmental biogenic carbonate material dredged from the nearby jetty, are banked against an erosional scarp up to 1m high in the older beach sands. As at Anse Kerlan on Praslin rock groynes have been constructed in an attempt to stem the erosion, but these seem to be providing no respite. Some 0.5km to the south-west of the jetty the coastline turns to face west and from that point southwards the shoreline is in an equilibrium condition with sands of the present-day beach banked up to the top of, and locally overwashing the older sand deposits.

Discussion and Conclusions

At all of the sites described in this paper the impact of erosion, or, in the case of Malindi, of sediment accretion, on coastal infrastructure is said to have become significant only since the early to mid-1970s. In all cases of major erosion and coastal recession reported

upon, the coasts comprise a flat hinterland of older beach sands and an intertidal to shallow subtidal reef-fringed platform of lithified lagoonal and littoral sediments, with an intervening sand strand. In all cases, by evidence of the existence of the commonly extensive older beach deposits, these shores were previously accretionary over a long term when the sea level was close, probably within 0.5m, to that of the present. What has caused these recorded changes in sedimentary regime within the last 20 years and are such changes remarkable or exceptional? Is there any evidence that they have been caused or influenced by man's activities?

The stability of beaches on shorelines such as these depends on an equilibrium being established between sediment supply and sediment wastage. The sources of sediment supply include biogenic material from the reef and platform, material derived from the hinterland by marine erosion, and terrigenous material introduced from rivers such as the Sabaki. Any of these sources may be subject to variation on long or short time scales due to sea level change, climatic variation or, as suggested for the Sabaki, land use changes. Wastage of beach sediment is similarly subject to variation with time, being exacerbated by storminess and by hard protective measures used by man, such as the sea walls on the Mombasa coast. Another important factor to be considered in the context of beach wastage is the effect of variation in the direction of longshore drift.

While the deep ocean current system may have a minor influence on the longshore regime on reef-fringed platforms and their beaches, the major influence is the wave climate during high water and, particularly, storm conditions. The seasonal variation in the pattern of prevailing winds affecting these latitudes in the western Indian Ocean, from the north or north-east between November and April and from the south for the rest of the year, is likely to have an important influence on the net direction of longshore drift on any specific shore. The evidence from Bahari Beach on the Dar-es-Salaam coast, Ras Nungwi on Zanzibar Island and from Praslin and La Digue in the Seychelles, where there is beach loss immediately south of granite headlands, supports the suggestion that a relative enhancement of the North-East Monsoon over the last 20 years or so may have been the determining influence in initiating and maintaining a net southward or south-westward drift at these sites during the period. The major accretion of sand from the Sabaki River in the Malindi bay may be another manifestation of this dominance. Detailed sedimentary studies and analysis of the regional climatic record will be necessary to explore the validity of this suggestion.

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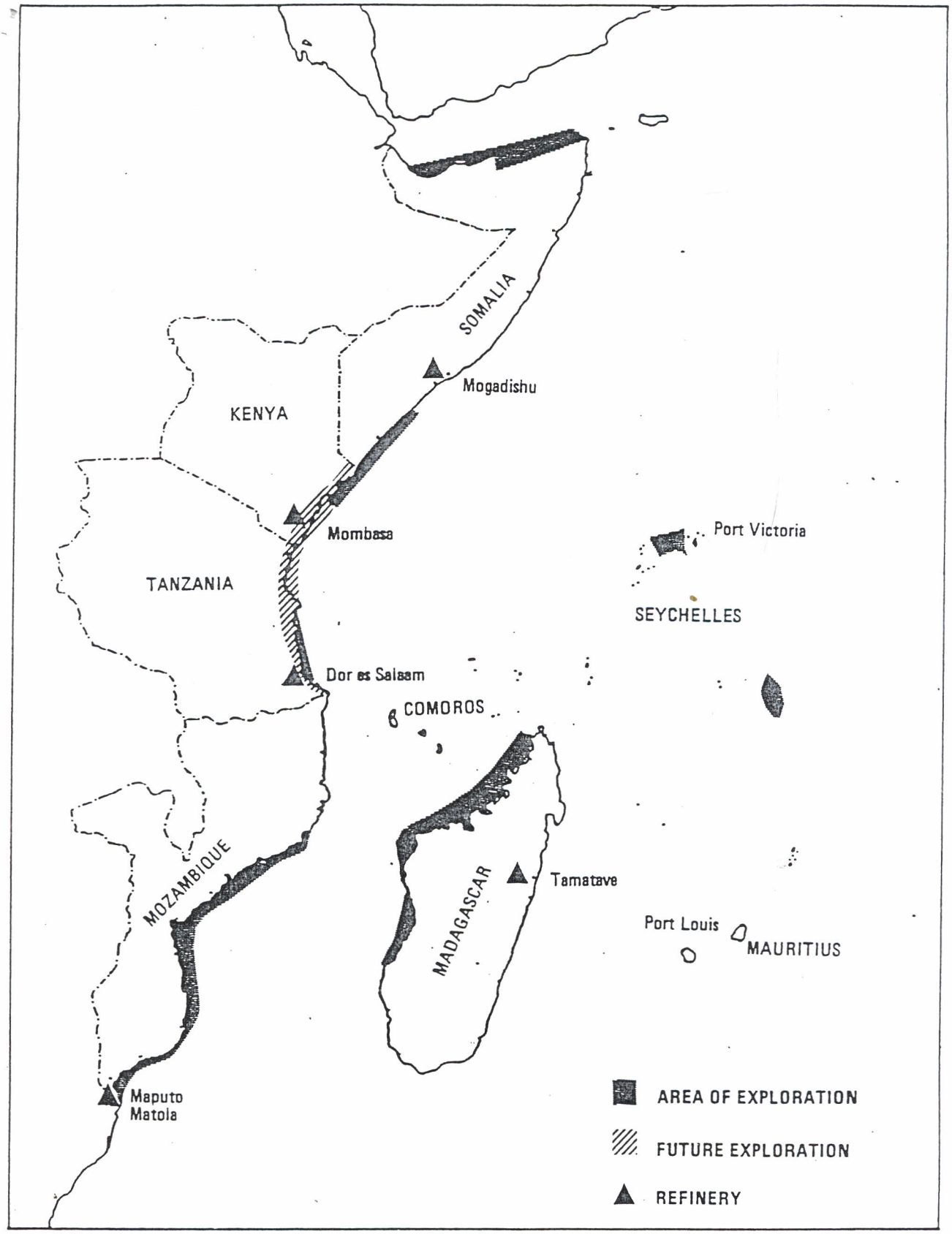

Fig 3: Oil exploration and refineries in Eastern Africa sub-region

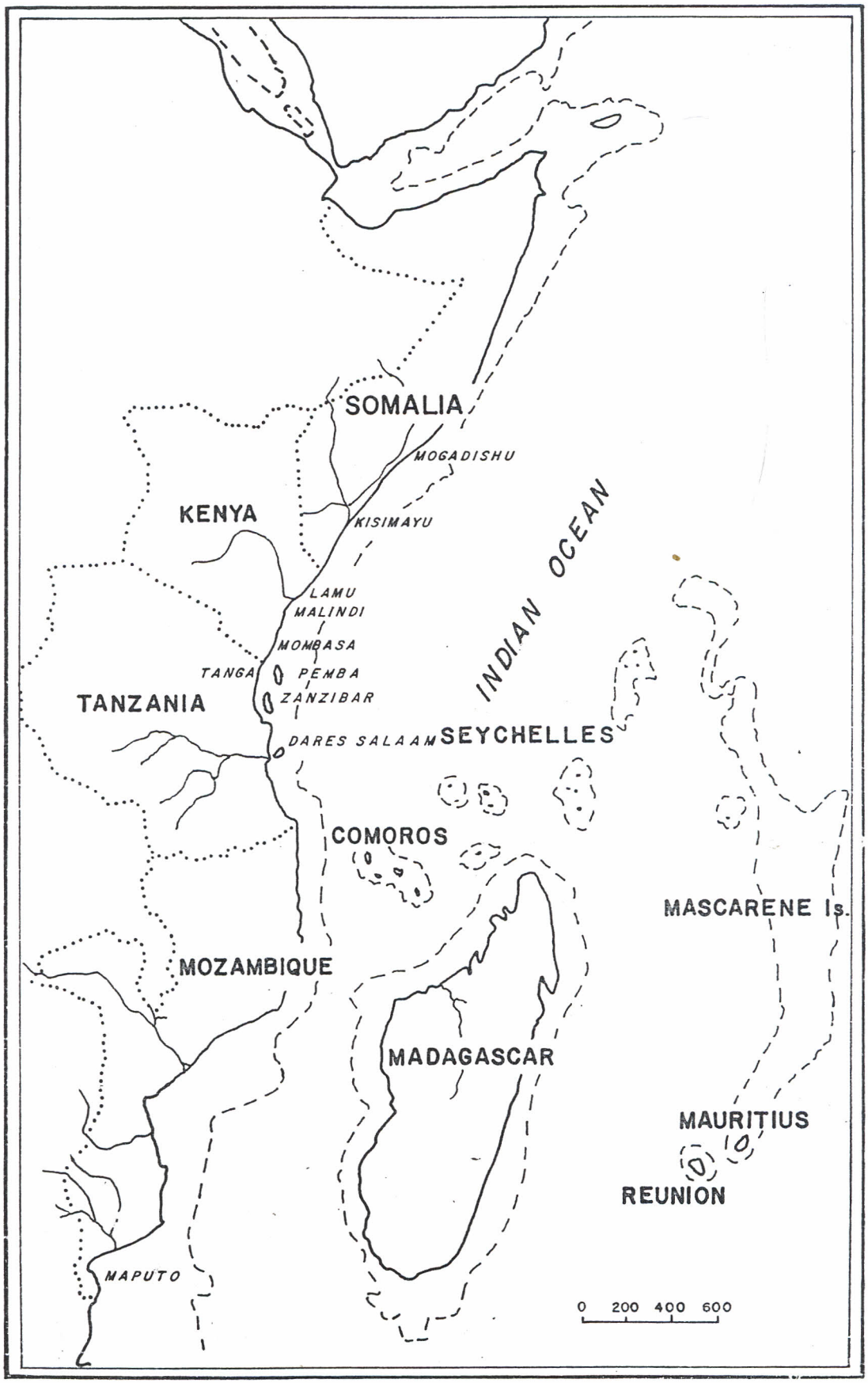

Figure 1: The East African Region. The dashed line represents the limits of the continental shelves and major banks in the Western Indian Ocean.